

MONITOR, CONTROL AND CONFIGURATION OF FIBER NODE VIA CABLE MODEM

TECHNICAL FIELD

The present invention relates generally to the field of cable networks and, in particular, to the control of fiber nodes of hybrid fiber-coax networks.

BACKGROUND

Hybrid fiber-coax networks are used to disseminate a variety of signals. For example, cable television operators typically use hybrid fiber-coax networks to transmit television signals to subscribers. Hybrid fiber-coax networks are often used to transmit other signals to subscribers and receive other signals from subscribers, e.g., a hybrid fiber-coax network may be connected to a data network, such as the Internet, and used to transmit data signals from the data network to subscribers and used to transmit data signals received from subscribers to the data network. Some hybrid fiber-coax networks transmit television signals to users and transmit data between subscribers and data networks.

Hybrid fiber-coax networks typically include a head end that functions as a distribution hub for the various signals. The head end typically includes receiving equipment for television signals and circuitry that interfaces with a data network, e.g., a cable modem transmission system (CMTS). Hybrid fiber-coax networks include fiber nodes that terminate runs of fiber cables emanating from the head end and that facilitate the dissemination of the various signals to neighborhoods of subscribers.

Fiber nodes are communicatively coupled to the head end over the fiber optic cable. Fiber nodes are also communicatively coupled to various subscriber equipment, e.g., cable modems, televisions, set top boxes, VCRs, telephones, and the like, over coaxial cables. Fiber nodes include a variety of equipment. Some existing hybrid fiber-coax networks allow the fiber nodes to be monitored and controlled from the head end. For example, it may be desirable to monitor the temperature of the fiber node from the head end and to adjust the operation of the node as necessary from the head end. Conventionally, establishing two-way communication between fiber-node equipment

and the head end has been accomplished by proprietary protocols that vary from vendor to vendor, are burdensome to develop and maintain, and are low-speed (e.g., less than 100 kbps).

For the reasons stated above, and for other reasons stated below which will become apparent to those skilled in the art upon reading and understanding the present specification, there is a need in the art for hybrid fiber-coax networks with a more economical and less burdensome method for monitoring and controlling a fiber node.

SUMMARY

The above-mentioned problems with monitoring and controlling equipment within a fiber node of a hybrid fiber-coax network from the head end of the network and the communication between the equipment and the head end that facilitates the monitor and control and other problems are addressed by embodiments of the present invention and will be understood by reading and studying the following specification. Embodiments of the present invention provide a hybrid fiber-coax network.

More particularly, in one embodiment the hybrid fiber-coax network has a head end and at least one fiber node in two-way communication therewith. A standards-based cable modem is located within the fiber node. The cable modem provides a communication channel. The communication channel is adapted to transmit at least one informational signal that is indicative of a condition of the fiber node to the head end and is adapted to receive at least one control signal from the head end.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a diagram demonstrating a first embodiment of the present invention.

Figure 2 is a diagram demonstrating a second embodiment of the present invention.

Figure 3 is a flow chart of the problem-identification operating mode of the second embodiment.

DETAILED DESCRIPTION

In the following detailed description, reference is made to the accompanying drawings that form a part hereof, and in which is shown by way of illustration specific illustrative embodiments in which the invention may be practiced. These embodiments are described in sufficient detail to enable those skilled in the art to practice the invention, and it is to be understood that other embodiments may be utilized and that logical, mechanical and electrical changes may be made without departing from the spirit and scope of the present invention. The following detailed description is, therefore, not to be taken in a limiting sense.

Embodiments of the present invention involve locating a cable modem utilizing the standards-based DOCSIS protocol in at least one fiber node of a hybrid fiber-coax network and using the cable modem to establish two-way communication between the fiber node and the head end of the network. Using a cable modem in this way is a simple, inexpensive alternative to the proprietary protocols used by some cable operators to establish two-way communication between the head end and the fiber node. For example, the readily available, relatively inexpensive data-over-cable service-interface-specification (DOCSIS) cable-modem can be used to establish the two-way communication. Two-way communication between the head end and the fiber node enables cable operators to monitor and control the fiber node from the head end. For example, monitor and control of the fiber node will enable cable operators to identify and alleviate many problems from the head end without having to dispatch technicians, thereby reducing costs and downtime.

Hybrid fiber-coax network 100, shown in Fig. 1, demonstrates a first embodiment of the present invention. Network 100 has at least one fiber node 102 and head end 104. Fiber node 102 is in two-way communication with head end 104 via lines 106 and 108. Lines 106 and 108 comprise one or more fiber optic cables that couple head end 104 and fiber node 102. Fiber node 102 includes cable modem 109, e.g., a data-over-cable service-interface-specification (DOCSIS) cable-modem. Cable

modem 109 provides a communication channel adapted to transmit at least one informational signal that is indicative of at least one condition of fiber node 102 to head end 104 and that is adapted to receive at least one control signal from head end 104, where the condition of fiber node 102 is any appropriate condition that impacts the ability of network 100 to transmit and receive signals from the cable subscribers.

Fiber node 102 receives a stream of signals from head end 104 via line 106 and transmits a stream of signals to the head end via line 108. In one embodiment, line 106 carries downstream signals in the range of 54 to 870 MHz, and line 108 carries signals in the range of 5 to 42 MHz. In other embodiments, other appropriate frequency ranges are used, e.g., upstream signals in the 5 to 65 MHz range.

Fiber node 102 has optical-to-electrical converter 110 that receives the stream of signals from head end 104 via line 106. Fiber node 102 includes amplifier 112 that is coupled to optical-to-electrical converter 110. Amplifier 112 is coupled to directional coupler 114. Directional coupler 114 is coupled to an input for cable modem 109. Directional coupler 114 is also coupled to pass signals to diplexer 116. Diplexer 116 is adapted to transmit the stream of signals from head end 104 to users via input-output line 118.

Fiber node 102 has electrical-to-optical converter 120 that transmits the stream of signals to the head end via line 108. Fiber node 102 has amplifier 122 that is coupled to electrical-to-optical converter 120. Amplifier 122 is also coupled to directional coupler 124. Directional coupler 124 is coupled to an output of cable modem 109. Directional coupler 124 is also coupled to receive signals from diplexer 116. Diplexer 116 is also adapted to receive the stream of signals that is transmitted to the head end from users via input-output line 118.

At least one of optical-to-electrical converter 110, electrical-to-optical converter 120, or amplifiers 112 or 122 is a controllable device that has at least one controllable condition determined by the operation thereof, where a controllable condition is any appropriate condition that impacts the ability of network 100 to transmit and receive

signals from the cable subscribers. For example, in one embodiment the gain of either or both of amplifiers 112 and 122 is controllable. In another embodiment, the power output, output amplitude, and/or the receive sensitivity of either or both optical-to-electrical converter 110 and electrical-to-optical converter 120 are/is controllable. In
5 another embodiment, the gain of either or both of amplifiers 112 and 122 is controllable and the power output, output amplitude, and/or the receive sensitivity of either or both optical-to-electrical converter 110 and electrical-to-optical converter 120 are/is controllable.

Fiber node 102 includes monitor and control circuit 126 that is coupled to
10 optical-to-electrical converter 110, electrical-to-optical converter 120, and amplifiers 112 and 122 via input-output lines 110a, 120a, 112a, and 122a, respectively. Monitor and control circuit 126 is also coupled to temperature sensor 111. In another embodiment, monitor and control circuit 126 is coupled to at least one of optical-to-electrical converter 110, temperature sensor 111, electrical-to-optical converter 120, or
15 amplifiers 112 or 122. Monitor and control circuit 126 receives at least one informational signal from at least one of optical-to-electrical converter 110, temperature sensor 111, electrical-to-optical converter 120, or amplifiers 112 or 122 via at least one of the respective input-output lines 110a, 111a, 120a, 112a, or 122a, the informational signal being indicative of at least one condition thereof, where a condition is any
20 appropriate condition that impacts the ability of network 100 to transmit and receive signals from the cable subscribers.

Cable modem 109 is coupled to monitor and control circuit 126 via input-output line 129 and receives the informational signal from monitor and control circuit 126. Cable modem 109 is coupled to directional couplers 114 and 124. Cable modem 109
25 transmits the informational signal to directional coupler 124, which injects the informational signal into the stream of signals from the users.

Network 100 has cable modem transmission system 130 located at head end 104 that is coupled to optical-to-electrical converter 132. Optical-to-electrical converter 132 is coupled to electrical-to-optical converter 120 via line 108 that carries the

informational signal and the stream of signals from the users. Network 100 includes monitor and control subsystem 134 located at head end 104 that is coupled to cable modem transmission system 130 via input-output line 136. Input-output line 136 is connected to cable modem transmission system 130 using an interface of the type used for ETHERNET connections. The informational signal is transmitted to monitor and control subsystem 134 from cable modem transmission system 130 via input-output line 136.

Monitor and control subsystem 134 evaluates the informational signal. For example, monitor and control subsystem 134 compares the informational signal to a preselected value indicative of an acceptable level for at least one of the controllable conditions of at least one of the controllable devices. If the comparison indicates that the informational signal is at an unacceptable level relative to the preselected value, monitor and control subsystem 134 transmits a control signal to cable modem transmission system 130 via input-output line 136 to alter the operation of the controllable device.

In other embodiments, monitor and control subsystem 134 determines whether any changes need to be made based on the received informational signal. For example, monitor and control subsystem 134 receives an informational signal from temperature sensor 111 indicative of the temperature of fiber node 102 and determines to alter the operation of amplifier 112 to change its gain based on the informational signal. Monitor and control subsystem 134 transmits a control signal that changes the gain of amplifier 112 based on the informational signal from temperature sensor 111.

Cable modem transmission system 130 is coupled to combiner 138 that is coupled to electrical-to-optical converter 140. Electrical-to-optical converter 140 is coupled to line 106. Cable modem transmission system 130 is also coupled to a data network and receives data signals therefrom. Cable modem transmission system 130 transmits the control signal and the data signal to combiner 138 that combines the control signal and the data signal with other signals, e.g., a video signal. In one embodiment cable modem transmission system 130 is not coupled to a data network,

and it transmits the control signal only to combiner 138.

The control signal and other signals are transmitted from head end 104 to directional coupler 114, where the signal is tapped off and to sent to cable modem 109. Cable modem 109 transmits the control signal to monitor and control circuit 126 via
5 input-output line 129. Monitor and control circuit 126 transmits the control signal to at least one of the controllable devices via the respective input-output line.

In operation, at least one informational signal is received by cable modem 109 that is indicative of at least one controllable condition of fiber node 102. Cable modem 109 transmits the informational signal to head end 104. The informational signal is
10 evaluated at head end 104. For example, the informational signal is compared to a preselected value indicative of acceptable level for the controllable condition. If the comparison indicates that the informational signal is at an unacceptable level relative to the preselected value, head end 104 transmits a control signal to cable modem 109 to alter the operation of fiber node 102. In other embodiments, the evaluation determines
15 whether any changes need to be made based on the received informational signal.

More specifically, the informational signal is transmitted from at least one controllable device (optical-to-electrical converter 110, temperature sensor 111, electrical-to-optical converter 120, or amplifiers 112 or 122) to monitor and control
20 circuit 126 via at least one of the respective input-output lines 110a, 111a, 120a, 112a, and 122a, the informational signal being indicative of at least one controllable condition thereof. The informational signal is transmitted from monitor and control circuit 126 to cable modem 109 via input-output line 129. The informational signal is transmitted from cable modem 109 to cable modem transmission system 130 via directional coupler 124, amplifier 122, electrical-to-optical converter 120, line 108, and optical-to-electrical
25 converter 132. The informational signal is transmitted from cable modem transmission system 130 via input-output line 136 to monitor and control subsystem 134, where it is evaluated.

In other embodiments, monitor and control subsystem 134 determines whether

any changes need to be made based on the received informational signal. For example, monitor and control subsystem 134 receives an informational signal from temperature sensor 111 indicative of the temperature of fiber node 102 and determines to alter the operation of amplifier 112 to change its gain based on the informational signal. Monitor
5 and control subsystem 134 transmits a control signal that changes the gain of amplifier 112 based on the informational signal from temperature sensor 111.

The control signal is transmitted from cable modem transmission system 130 to cable modem 109 via combiner 138, electrical-to-optical converter 140, line 106, optical-to-electrical converter 110, amplifier 112, and directional coupler 114. The
10 control signal is transmitted from cable modem 109 to monitor-and-control circuit 126 via input-output line 129. The control signal is transmitted to at least one controllable device via the respective input-output line to alter its operation.

Hybrid fiber-coax network 200, shown in Fig. 2, demonstrates a second embodiment of the present invention. Network 200 has at least one fiber node 202 and
15 head end 204. Fiber node 202 is in two-way communication with head end 204 via lines 206 and 208. Lines 206 and 208 comprise one or more fiber optic cables that couple head end 204 and fiber node 202. Fiber node 202 includes cable modem 209, e.g., a data-over-cable service-interface-specification (DOCSIS) cable-modem. Cable modem 209 provides a communication channel adapted to transmit at least one
20 informational signal that is indicative of a condition of fiber node 202 to head end 204 and that is adapted to receive at least one control signal from head end 204, where the condition of fiber node 202 is any appropriate condition that impacts the ability of network 200 to transmit and receive signals from the cable subscribers.

Fiber node 202 receives a stream of signals from head end 204 via line 206 and
25 transmits a stream of signals to the head end via line 208. In one embodiment, line 206 carries downstream signals in the range of 54 to 870 MHz, and line 208 carries signals in the range of 5 to 42 MHz. In other embodiments, other appropriate frequency ranges are used, e.g., upstream signals in the 5 to 65 MHz range.

Fiber node 202 has optical-to-electrical converter 210 that receives the stream of signals from head end 204 via line 206. Fiber node 202 includes amplifier 212 that is coupled to optical-to-electrical converter 210. Amplifier 212 is coupled to directional coupler 214. Directional coupler 214 is coupled to an input of cable modem 209.

5 Directional coupler 214 is also coupled to pass signals to each of diplexers 216_1 to 216_N via lines 217_1 to 217_N , respectively. Each of diplexers 216_1 to 216_N is adapted to respectively transmit the stream of signals received from the head end to users via input-output lines 218_1 to 218_N . These signals are respectively transmitted over a downstream line of each of input-output lines 218_1 to 218_N .

10 Fiber node 202 has electrical-to-optical converter 220 that transmits the stream signals to the head end via line 208. Fiber node 202 has amplifier 222 that is coupled to electrical-to-optical converter 220. Amplifier 222 is also coupled to directional coupler 224. Directional coupler 224 is coupled to an output of combiner 225. Inputs of combiner 225 are respectively coupled to each of switches 227_1 to 227_N .

15 Switches 227_1 to 227_N are coupled to each of diplexers 216_1 to 216_N , respectively, by each of lines 219_1 to 219_N , respectively. Diplexers 216_1 to 216_N are adapted to respectively transmit the stream of signals received from users via input-output lines 218_1 to 218_N in the upstream frequency band, e.g., 5-to-42 MHz band. These signals are received from the users over an upstream line of input-output lines
20 218_1 to 218_N .

Fiber node 202 includes monitor and control circuit 228 that is coupled to each of switches 227_1 to 227_N via input-output lines 228_1 to 228_N , respectively. Cable modem 209 is coupled to monitor and control circuit 228 via input-output line 229. An input and output of cable modem 209 are respectively coupled to directional couplers
25 214 and 224.

Network 200 has cable modem transmission system 230 located at head end 204 that is coupled to optical-to-electrical converter 232. Optical-to-electrical converter 232 is coupled to electrical-to-optical converter 220 via line 208. Network 200 includes

monitor and control subsystem 234 located at head end 204 that is coupled to cable modem transmission system 230 via input-output line 236. Input-output line 236 is connected to cable modem transmission system 230 using an interface of the type used for ETHERNET connections.

5 Cable modem transmission system 230 is coupled to combiner 238 that is coupled to electrical-to-optical converter 240. Electrical-to-optical converter 240 is coupled to line 206. Cable modem transmission system 230 is also coupled to a data network and receives data signals therefrom. Combiner 238 also receives other signals, e.g., video signals, and combines them with data signals. In one embodiment cable
10 modem transmission system 230 is not coupled to a data network.

Operation of hybrid fiber-coax network 200 comprises a normal operation mode and a problem identification mode. The problem identification mode identifies at least one problematic upstream line of input-output lines 218_1 to 218_N . Note that a signal is received at each of switches 227_1 to 227_N from the upstream lines of input-output lines
15 218_1 to 218_N , respectively. Each of these signals will be referred to as an upstream signal in the ensuing discussion.

In the normal operation mode, an upstream signal from an upstream line of each of input-output lines 218_1 to 218_N is transmitted to one of duplexers 216_1 to 216_N , respectively, in the upstream frequency band, e.g., 5-to-42-MHz band. The respective
20 upstream signals are transmitted as signals S_1 to S_N to switches 227_1 to 227_N , respectively. The respective switches transmit the upstream signals to combiner 225 that combines these signals to form combined signal $S_{1+2+...N}$.

Combiner 225 transmits combined signal $S_{1+2+...N}$ to monitor and control subsystem 234 via directional coupler 224, electrical-to-optical converter 220, line 208,
25 optical-to-electrical converter 232, cable modem transmission system 230, and input-output line 236. Monitor and control subsystem 234 evaluates combined signal $S_{1+2+...N}$ by comparing it to at least one preselected value indicative of an acceptable level for at least one performance parameter of the combined upstream signal, e.g., the signal-to-

noise ratio of the combined upstream signal. If the comparison indicates that the level of at least one performance parameter of combined signal $S_{1+2+...N}$ is at an unacceptable level relative to the preselected value, an indication of a problem in the upstream line of at least one of input-output lines 218₁ to 218_N, the problem identification mode is initiated.

The problem identification mode is demonstrated by the flowchart of Fig. 3. The problem identification mode demonstrated in Fig. 3 commences at block 300 with receiving combined upstream signal $S_{1+2+...N}$ at monitor and control subsystem 234, indicating a problem in the upstream line of at least one of input-output lines 218₁ to 218_N. In one embodiment, the problem identification mode includes monitor and control subsystem 234 evaluating combined signal $S_{1+2+...N}$ and determining that a problem in the upstream line of at least one of input-output lines 218₁ to 218_N exists.

At block 310, monitor and control subsystem 234 selects line 219₁ to be disabled. At block 320, monitor and control subsystem 234 transmits a control signal to cable modem transmission system 230 via input-output line 236. Cable modem transmission system 230 transmits the control signal to cable modem 209 via combiner 238, electrical-to-optical converter 240, line 206, optical-to-electrical converter 210, amplifier 212, and directional coupler 214. The control signal is transmitted to monitor and control circuit 228 via input-output line 229. At block 330, monitor and control circuit 228 transmits the control signal to switch 227₁ to disable line 219₁, preventing corresponding upstream signal S_1 from being combined with the remaining upstream signals.

At block 340, monitor and control subsystem 234 evaluates combined upstream signal $S_{1+2+...N}$ less upstream signal S_1 as described above. At block 350, monitor and control subsystem 234 determines if the problem is alleviated based on the evaluation. If an acceptable level is indicated, monitor and control subsystem 234 identifies the upstream line of input-output line 218₁ as the problematic line at block 360. If the level is still unacceptable, monitor and control subsystem 234 transmits a control signal at block 370 to switch 227₁ to enable line 219₁, allowing corresponding upstream signal S_1

to be combined with the remaining upstream signals. At block 380, monitor and control subsystem 234 selects line 219₂ to be disabled, and the process is repeated for each of switches 227₁ to 227_N until the problematic upstream line is identified, as demonstrated in the flowchart in Fig. 3. In one embodiment, after the problematic upstream line is
5 identified, a control signal is transmitted from monitor and control subsystem 234 to the problematic line via cable modem 209 that alleviates the problem.

Conclusion

10 Embodiments of the present invention have been described. The embodiments provide a hybrid fiber-coax network having a head end and at least one fiber node that has a cable modem, where the cable modem enables monitor and control of the fiber node by the head end.

15 Although specific embodiments have been illustrated and described in this specification, it will be appreciated by those of ordinary skill in the art that any arrangement that is calculated to achieve the same purpose may be substituted for the specific embodiment shown. This application is intended to cover any adaptations or variations of the present invention. For example, an amplifier may be placed between combiner 225 and each of switches 227₁ to 227_N.